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Meloidogyne enterolobii resistance in cultivated and wild guava: A review

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Abstract
Guava holds significant economic value for small, medium, and large-scale guava growers worldwide, contributing substantially farm revenue. Root-knot nematode *Meloidogyne enterolobii* is now becoming a significant threat to guava production globally. *Meloidogyne enterolobii* infected guava orchards are diagnosed through the symptoms like stunted growth, branch drying, reduced vigor, decreased productivity and plant wilting. Various nematode management strategies like cultural, biological and chemical have established against this nematode pest on guava. However, host plant resistance can be a permanent solution considering cost economics and sustainability. Various efforts made across the globe to explore *M. enterolobii* resistance in guava on various aspects. This manuscript provides an overall progress made on guava nematode resistance by inclusion of total list of guava varieties/species with resistance, their mode of resistance mechanism, current status of utility of resistance sources on developing nematode resistant guava grafts, induction of systemic resistance in guava and future prospects are dealt. This review will be useful for nematologists and breeders to move forward the existing *M. enterolobii* resistance programme in a holistic way.

Keywords: Guava**,** *Meloidogyne enterolobii*, Host plant resistance

1. Introduction

Guava (*Psidium guajava* L), widely known as the "poor man's fruit," holds a prominent position among commercial fruits in India. It belongs to the Myrtaceae family, which encompasses various fruit-bearing trees; Guava is the fourth ranked fruit crop after mango, banana and citrus. These trees thrives in diverse tropical and subtropical regions. The typical guava variety is diploid with a chromosomal count of 2n = 22. Occasionally, natural and engineered triploid variations (2n = 33) also exist naturally in guava. The *Psidium* genus comprises more than 150 species of evergreen shrubs and trees distributed across various tropical climate. Some of the important species are *Psidium chinensis*, *Psidium guineense* and *Psidium cattleianum*, *Psidium montanum*, *Psidium friedrichsthalianum* and *Psidium eugeniaefolia*.

Guava is affected by various biotic stress factors like fungal diseases, insect and nematode pests. According to research conducted across the globe the guava is home to a variety of nematodes with distinct feeding behaviours. About 72 nematode species are associated with the guava crop in commercial production areas (McSorley 1992) [29]. Nine distinct taxa such as *Tylenchorhynchus, Hoplolaimus, Rotylenchulus, Helicotylenchus, Pratylenchus, Criconemoides, Longidorus, Xiphinema* and *Meloidogyne* have been reported in the guava rhizosphere (Khan *et al.*, 2007) [25]. Among them, root-knot nematode *Meloidogyne enterolobii* represent a significant barrier to the production of guava. *Meloidogyne enterolobii* is a polyphagous phytonematode that feeds on woody plants (Gomes *et al.*, 2008) [19]. It was first reported in Pacara ear pod trees (*Enterolobium contortisiliquum*) in china (Yang and Eisenback 1983) [45]. Common signs of *M. enterolobii* infection in guava plants include stunted growth, leaf yellowing, leaf shredding, branch drying, reduced vigor, decreased productivity and plant wilting. The presence of this nematode also makes the plants more susceptible to secondary plant pathogens like *Fusarium solani*, which worsens the overall disease condition (Gomes *et al.*, 2011) [21]. *Meloidogyne enterolobii* thrives in crop varieties with *M. incognita* and *M. javanica* resistant genes such as *Capsicum annum* cv. (N gene, Tabasco gene), *Vigna unguiculata* (Rk gene), *Glycine max* (Mir1 gene), *Gossypium hirsutum*, *Ipomoea batatas*, *Solanum lycopersicum* (Mi-1 gene) and *Solanum tuberosum* (Mh gene) (Schwarz *et al.*, 2021) [37].

The strategies available for managing *M. enterolobii* in guava involve are organic compost, utilizing antagonistic plants to deter its growth, biocontrol agents and identifying guava cultivars or rootstocks that exhibit resistance (Chiamolera *et al.,* 2018) [10]. Among these methods, host plant resistance is considered both cost-effective and ecologically sound for eliminating *M. enterolobii* (Ayala-Doñas *et al.,* 2020) [5].

Around the world, numerous research projects have been implemented to explore and to establish host plant resistance against *M. enterolobii* in cultivated and wild guava. The manuscript provides an overview of the status of *M. enterolobii* resistance research including total list of guava varieties/species with resistance, their mode resistance mechanism, current status of utility of resistance sources on developing nematode resistant guava grafts and future prospects are dealt.

2. Reaction of different guava varieties and species to root-knot nematode

Ashokkumar *et al.,* (2019) [4] performed screening on 15 different guava cultivars to assess their susceptibility or reaction to *M. enterolobii* based on the evaluation of gall index in root and reproduction factor. The results indicated that along these cultivars, five of them, namely mini guava, red seedless, white seedless, Paneer guava and local variety shows susceptibility and remaining ten cultivars including Allahabad safeda, lucknow 49, Thailand red, banaras, Lucknow 46, Beetroot guava, Trichy 1, chitdar and Taiwan guava were found to be highly susceptible.

Sreekavya *et al.,* (2019) [44] screened *Psdium Cattleianum* and *Psidium guajava* species against *M. enterolobii* and found that *P. cattleianum* shown resistant action against *M.enterolobii* without inducing hypersensitive reaction with fewer root galls, minimal feeding site and Reproduction Factor was zero where as in *P. guajava* have greater number of root galls.

Chiamolera *et al.,* (2018) [10] screened seven species of guava and observed that *Psidium cattleianum var xysopersicum* and *Psidium friedrichsthalianum* have shown resistance to *M. enterolobii* with Reproduction Factor (RF=0) and has fewer root galls when compared to other guava species, whereas susceptible varieties showed a greater number of root galls as well as RF value range between 1.8 to3.4

In a study conducted by SOUSA *et al.,* (2017) [43] on the invasion, growth and reproductive patterns of *M. enterolobii* within different *Psidium* species including *P. guajava* cv paluma, *P. guineense* and *P. cattleianum* sourced from the Active Germplasm Bank (BAG) at the Centre for Agricultural Research in Semiarid Tropics, Brazil. Their findings shown that *P. guajava* exhibited susceptibility, whereas *P.cattleianum* shown resistance to *M. enterolobii.* Furthermore histological analysis indicated that other than *Psidium guajava* spp the remaining species exhibited minimal feeding sites after 20 days of inoculation and categorized as tolerant/resistant.

Freitas *et al.,* (2014) [16] in Brazil, examined 51 different accessions of *Psidium* germplasm to assess their resistance to *M. enterolobii*. Their investigation revealed that *P. cattleianum* (yellow), *P. friedrichsthalianum* (Costa Rica), *Acca sellowiana* and *P. rufum* (purple) exhibited resistance to nematode infestation without inducing a hypersensitive response (HR). Out of the 43 *P. guajava* accessions tested, all were found to be susceptible to root-knot nematodes.

Martins *et al.,* (2013) [26] screened aruaca genotypes of *Psidium* species. The seedlings AUFLA1, AUFLA4, AUFLA5, APASTO, G-ROXA, G - AMA were found to be resistant. Carneiro *et al.,* (2012) [7] screened 16 isolates of *Psidium* species against *M. enterolobii*. Only one accession (Costa Rican wild guava) of *P. friedrichstalianium* has shown resistance

Castro *et al.,* (2012) [8] Among 66 *Psidium* spp including, 14 araca zeiro (wild guava) and 52 araca zeiro accessions were screened against *M. enterolobii* under nursery and greenhouse condition by in Brazil, 3 wild accessions of them were resistant with RF<1 and 9 were considered as immune with RF=0.

Gomes *et al.,* (2017) [20] performed interspecific crosses between three different species: *P. guineense* (susceptible araca) x *P. cattleyanum* (resistant araca), *P. guineense* (susceptible araca) x *P. guajava* (susceptible guava) and *P. cattleyanum* (resistant araca) x *P. guajava* (susceptible guava). In these crossings, 30 hybrid emerged have shown immune and resistant reaction to *M. enterolobii*. Da Costa *et al.,* (2012) [12] also observed that hybrids obtained by crossing *P. guajava* GUA 161 PE with *P. guineense* ARA 138 RR accessions showed significant tolerance to *M. enterolobii*, with no gall formation or Reproduction Factor was zero, while hybrids from the cross between *P. guajava* GUA 161 PE and *P. guineense* ARA 153 BA accessions shown susceptibility to the nematode.

Sixty eight accessions of guava were examined to assess their susceptibility to root-knot nematode. In which, three accessions K-10, A-06 and J-16 had strong resistance and one accession exhibited a moderate degree of resistance to *M. enterolobii* (Milan 2008) [30]. In a research conducted by Abd Rahman *et al.,* (2008) [1] various *Psidium* spp including *P. littoralle var. longipes, P. arayan*, naturally grown *P. guajava*, and *P. guajava var. Kampuchea* (GU 8) examined for their resistance to *M. enterolobii*. The results of the screening indicated that *P. littoralle var. longipes, P. arayan*, and *P. guajava* Acc. B-12 exhibited resistance reaction against *M. enterolobii*.

Carneiro *et al.,* (2007) [6] screened various accessions of *Psidium* species against *Meloidogyne mayaguensis.* Accessions of *P. guajava* exhibited significant susceptibility. *Psidium friedrichsthalianium* shows a moderate level of resistance (RF=1.9). Moreover, three accessions of *P. cattleyanum* displayed immunity to *M. mayaguensis*, with an RF value of 0. Cuadra and Quincosa (1982) [11] discovered that Costa Rican guava *(Psidium friedrichsthalianum*) was particularly resistant to *Meloidogyne* species.

Globally, six guava species and seven guava accessions/varieties have established as a resistant source for *M. eneterolobii* are given in Table 1. The susceptible guava species and varieties are given in table 2. The important characteristics of these resistant and susceptible species or varieties are also given that are useful for guava nematode resistant breeders.

Table 1: *Meloidogyne enterolobii* resistant varieties/species /accessions of guava

S. No	Resistant Guava varieties/species/ accessions	Reference
1	*Psidium cattleianum var xysopersicum*	Chiamolera *et al.*, (2018) [10]
2	*P. cattleianum var lucidum*	Sreekavya *et al.*, (2019) [44]
3	*Psidium friedrichsthalianum*	Chiamolera *et al.*, (2018) [10]
4	*Psidium guineense*	Da Costa *et al.*, (2012) [12].
5	*Acca sellowiana*	Freitas *et al.*, (2014) [16]
6	*Psidium rufum*	Freitas *et al.*, (2014) [16]
7	AUFLA1	Martins *et al.*, (2013) [26]
8	AUFLA4	Martins *et al.*, (2013) [26]
9	AUFLA5	Martins *et al.*, (2013) [26]
10	APASTO	Martins *et al.*, (2013) [26]
11	G-ROXA	Martins *et al.*, (2013) [26]
12	G- AMA	Martins *et al.*, (2013) [26]
13	*P. guajava* accession S3	(Freitas *et al.*, 2014) [16]

2.1 Description of *Meloidogyne enterolobii* resistant guava varieties/species/accessions

***Psidium cattleianum*:** It is a small tree or shrub, mostly present in China, features a smooth bark and emits a pleasant fragrance reminiscent of strawberries (McCook-Russell *et al.*, 2012) [28].

***Psidium friedrichsthalianum*:** This species is characterized by glossy upper leaf surfaces with a pubescent underside; small spherical shape fruits possess a sour taste. Mostly found in Costa Rica and exhibits dwarfing traits. This species were resistant against wilt (Morton 1987).

***Psidium guineense*:** It is mostly grown in Brazil, fruits are Pear or round shaped fruits known for its tolerance to wilt (Morton 1987).

***Psidium rufum*:** They are mostly present in Brazil, fruit of *P. rufum* is smooth, shiny, hairless, with a red-purple color, when ripe fruits become fleshy and indehiscent type. The seeds are reniform with stony seed coat (Soares *et al.*, 2017) [42].

***Acca sellowiana*:** It is native to the southern highlands of Brazil, flowers are hermaphrodite ellipsoid. Fruits have sweet, aromatic flavor and the flesh is juicy, divided into a clear gelatinous seed pulp (Ramírez and Kallarackal 2017) [34].

Table 2: *Meloidogyne enterolobii* susceptible varieties/species of guava

S. No	Susceptable Guava varieties/species	Reference
1	*Psidium chinnensis*	Sreekavya *et al.*, (2019) [44]
2	*Psidum acutangulum*	Freitas *et al.*, (2014) [16]
3	Paluma	Carneiro *et al.*, (2012) [7]
4	Lalit	Sreekavya *et al.*, (2019) [44]
5	Hafsi	Sreekavya *et al.*, (2019) [44]
6	Banaras	Sreekavya *et al.*, (2019) [44]
7	Black guava	Sreekavya *et al.*, (2019) [44]
8	ArkaPoorna	Sreekavya *et al.*, (2019) [44]
9	ArkaReshmi	Sreekavya *et al.*, (2019) [44]
10	ArkaMridula	Ashokkumar *et al.*, (2019) [4]
11	Allahabad safeda	Ashokkumar *et al.*, (2019) [4]
12	Taiwan white	Ashokkumar *et al.*, (2019) [4]
13	Lucknow-46	Ashokkumar *et al.*, (2019) [4]
14	Lucknow-49	Ashokkumar *et al.*, (2019) [4]
15	Bapatla	Ashokkumar *et al.*, (2019) [4]
16	Taiwan pink	Ashokkumar *et al.*, (2019) [4]

2.2 Description of *Meloidogyne enterolobii* susceptible guava varieties/species

***Psidium chinensis*:** This wild species is found in India. Fruit of *Psidium chinensis* is characterized by its smooth green exterior and pear-like shape. It exhibits a suckering habit and is known for its natural resistance to fruit flies (Saroj and Pathak 1998) [36].

***Psidium acutangulum*:** This species originated from Brazil, characterized by elliptical leaves with minimal petioles. The fruits range from pear to round shapes with pale yellow to yellowish-white acidic pulp with triangular shape seeds (Morton 1987).

Allahabad Safeda: It is primarily cultivated in the regions of Uttar Pradesh and Andhra Pradesh, characterized by its large round fruits with smooth skin, encompassing white, tender, and firm flesh. This variety offers a delightful taste and features a minimal number of seeds (Dinesh and Vasugi 2010) [13].

Lucknow-49: It is mostly found in the states of Andhra Pradesh and Tamil Nadu. Highly productive variety, characterized by its greenish-yellow hue outer surface and milky-white flesh. The pulp has relatively small number of soft seeds, while the fruit's exterior has a slightly textured surface (Cheema 1954) [9].

Arka Kiran: It is a hybrid obtained from crossing 'Kamsari' with 'Purple Local' and mostly grown in the Karnataka region. These plants have a semi-vigorous growth pattern and suitable for planting at high densities. The fruit is somewhat round in shape; flesh of the fruit is a rich shade of pink and possesses a thick texture, offering a delightful flavor. Notably, it contains a high amount of lycopene, measuring 7.45 mg per 100g. Total soluble solids (TSS) level ranges from 12.0 to 12.5°Brix, indicating its sweetness (Dinesh and Vasugi 2010) [13].

Arka Mridula: It is a hybrid obtained by crossing Allahabad Safeda with a Triploid variety. The plants exhibit strong and expansive growth, while the fruits are medium size. This cultivar hails from Karnataka and boasts a high Total Soluble Solids (TSS) content, coupled with excellent shelf life (Dinesh and Vasugi 2010) [13].

Anakapalli: The fruits from Anakapalli are of medium size, featuring red pulp and a slightly oval shape, and contain numerous soft seeds (Dinesh and Vasugi 2010) [13].

Taiwan Pink: This variety is prominently grown in the Andhra Pradesh region. Characterized by its sizable rounded shape and impressive ability to maintain freshness, making it suitable for both consumption as fresh fruit and for various processing purposes. The mesocarp or middle layer of the fruit, exhibits shades ranging from pink to red and fruits holds a moisture content within the range of 79.2% to 85.9%, while its total soluble solids (TSS) level remains below 9% (Yusof 1989) [47].

Arka Amulya: It is a triploid variety of Allahabad Safeda, exhibits semi-vigorous growth and a spreading growth pattern. It is commonly found in the Karnataka region. The pulp of this variety is characterized by its white color, elevated Total Soluble Solids (TSS) content and impressive shelf life (Dinesh and Vasugi 2010) [13].

Lalit: It was chosen from a half-sibling group of apple cultivars based on its distinct characteristics. The flesh of this type is both firm and pink, offering a pleasing balance of sweetness and acidity. Mostly grown in Uttar Pradesh, the fruits are medium size, featuring an appealing saffron yellow hue with a noticeable red blush (Pommer and Murakami 2009) [33].

3. Resistance mechanisms of guava species / varieties / accessions against *M. enterolobii*

3.1 Biochemical mechanism

When a root-knot nematode infects many biochemical processes take place in the guava plant, as a result the plant may either overcome or become susceptible to nematode infection. To increase our knowledge of the interaction between plants and nematodes, detailed characterization of biochemical composition is required. Various authors proposed the changes in biochemical composition of resistant and susceptible plants affected by root-knot nematodes. Kavya *et al.*, (2019) [24] observed the biochemical alterations occurred in guava plants infested with *M. entereolobii* under controlled conditions. Notable distinctions were observed in the levels of total chlorophyll, total phenol, total sugar, total proline, total protein content, and the activity of enzymes like Peroxidase and Polyphenol Oxidase between plant varieties that were resistant and susceptible. The *M. enterolobii* resistant varieties/species such as Banaras, Arka Mridula, *P. cattleianum* and *P. guineense* exhibited an increase in phenol, proline, protein, peroxidase, and polyphenol oxidase activity. Susceptible varieties such as Lucknow-49, Bapatla, Taiwan pink, Allahabad safeda, Luaknow-46 and Arka Amulya affected by *M. enterolobii* also shows significant increase in biochemical traits, excluding chlorophyll content but in less extent when compared to resistant varieties /species.

EL-BELTAGI *et al.*, (2012) [15] observed that when tomato plants were infected with root-knot nematodes, their defense mechanisms responded by enhancing levels of antioxidant substances and enzyme activities. This defensive response was characterized by an increase in overall phenolic compounds, as well as higher activities of the enzymes PPO (Polyphenol oxidase) and peroxidase. In the case of varieties that exhibited resistance to root-knot nematodes, the increase in peroxidase activity was particularly notable, showing a fivefold rise in ten days after inoculation, compared to the susceptible tomato cultivars.

Singh and Choudhury (1974) [41] conducted an analysis of biochemical parameters in tomato cultivars. The study found that among the resistant and immune cultivars, exhibited the highest levels of phenolics, followed by resistant, tolerant, and susceptible cultivars. Similarly, phosphorus content was more in susceptible cultivars, no significant variation in amino acid content was observed between the resistant and susceptible tomato cultivars.

Gautam and Poddar (2014) [17} focused on analyzing the protein and sugar content within the roots of bitter gourd plants that had been subjected to infestation by *Meloidogyne incognita*. Their findings indicated that there is high increase in protein levels occurred during the initial week of infestation. This rise in protein synthesis early seems to play a crucial role in initiating primary resistance mechanisms in plants as a defense against nematode attacks. .

Shukla and Chakraborty (1988) [38] revealed that there was a 12-18% rise in polyphenol oxidase activity among *M. incognita* resistant tomato cultivars and there is a 16-24% overall increase in polyphenol oxidase activity in susceptible cultivars.

Giebel (1974) [18] Stated that Phenolic compounds play a crucial role in influencing the susceptibility or resistance of plants. The variation in phenolic compound composition within plant tissues is associated with the extent of plant resistance. These phenols are sometimes found in an inactive bound form as glycosides. Nematodes can induce the liberation of active phenols by releasing flavo-glycosidases into the host tissue. This process involves breaking down the glycosides, leading to the release of free phenols.

3.2 Giant cell deterioration

The guava species like *P. cattleianum* and *P. friedrichsthalianum* did not show any biochemical reaction against *M. enterolobii*, However they excibited resistant reaction through deterioration of giant cell formation. Fourth stage juvenile were seen but it does not developed into fully grown females. Presence of Thin cytoplasm with devoid of cyoplasmic content in giant cell and larger vacoules was considered as a mechanism of resistance. This kind of giant cell deterioration arrest nematode growth (Freitas *et al.,* 2014) [16].

3.3 Root exudates compounds

Compounds present in root exudates have the capability to attract or deter nematodes towards the roots. The resistant/immune varieties of crop plants are reported to have the deter principle against the nematodes. The resistance principles on root exudates of guava has not yet studied. In a study conducted by Yang *et al.,* (2016) [45] observed that root exudates from the highly resistant tomato variety, Balaiya, showed a repellent impact on the second-stage juveniles (J2) of root-knot nematodes. Conversely, the susceptible plant L-402 exhibited an attraction of nematodes towards its exudates. Four specific compounds such as 2, 6-Di-tert-butyl-p-cresol, L-ascorbyl 2,6-dipalmitate, Dibutyl phthalate, and Dimethylphthalate present in the root exudates of the highly resistant variety had nematode toxic effect and caused mortality of juvenniles of M. *incognit*a. Among these compounds, dibutyl phthalate has repellent properties against *M. incognita,* while the other compounds did not exhibit repellent effects.

Small lipophilic molecules (SLM) present in the root exudates of *Solanum lycopersicum* and *Oryza sativa* inhibit motility, stylet thrusting, nematode head movement and reduces the salivary secretion of second-stage juveniles of *Meloidogyne incognita* and *M. graminicola.* This might exert a repellent or allellopathic effect on these nematodes (Dutta *et al.,* 2012) [14].

Root exudates of *Meloidogyne graminicola* resistant rice variety Huaidao 5 did not have the repellent effect on this nematode (Hui *et al*., 2022) [22].

4. Development of guava Grafts for *M. enterolobiii* resistance

Identification of suitable rootstocks resistant to *M. enterolobii* is mandatory for developing high yielding commercial guava varieties through grafting techniques to overcome nematode menace. Three *M. enterolobii* resisant guava accessions K-10, A-06 and J-16 shown compatibility with the prevailing local commercial guava clones in Malaysia as they belong to the same *Psidium guajava* L. species (Milan 2008) [30].

Castro *et al.*, (2012) [8] observed that three resistant accessions and nine immune accessions of araca zeiros shows low degrees of graft compatibility with commercial guava cultivars. Only *P.guineense* shows compatability to paluma guava variety. Robaina *et al.,* (2015) [35] observed reduced success rate of grafting observed between 'Paluma' variety of *P. guajava* and *P. cattleyanum* plants. In this graft, the weak growth of saplings in the field indicated its incompatibility and cattley guava variants cannot be used as rootstocks for 'Paluma' guava. (Freitas *et al.,* 2014) [16] demonstrated the compatability of *P. cattleianum* and *P. friedrichsthalianum* as rootstocks with *P. guajava* cv paluma in greenhouse conditions.Howeer the survival of the scion was only 50% under field condition.

Carneiro *et al.*, (2007) [6] confirmed the graft compatibility of *P. friedrichsthalianium* and *P. cattleyanum* species to *P. guajava* cv. Paluma with 50% success rate.

5. Inducing nematode resistance in guava plants through bio-inoculants

Various commercial biocontrol agents such as *Pochonia chlamydosporia, Purpureocilium lilacinum, Bacillis subtilis* and *Trichoderma harzianum* has been found to exhibit various mode of action such as antibiosis, parasitism, lysis and production of various secondary metabolites which has direct and indirect action over nematodes. Moreover, they also has the potential to induce the systemic resistance in plants by activating various pathways (Nagachandrabose, 2022; Nagachandrabose, 2021) [31, 32].

In a study conducted by Arshad *et al.,* (2021) [2] showed that *Bacillus subtilis* application in tomato plants led to improved plant growth and reduce the damage caused by *M. incognita* through activation of defense gene. They used quantitative real-time polymerase chain reaction (qRT-PCR) to analyze the expression of two resistance genes, namely PR-1b and JERF3. The results indicated that the expression of PR-1b and JERF3 significantly increased at 6 days post inoculation (dpi) of nematodes in plants treated with *B. subtilis*. These findings highlight the effectiveness of using *B. subtilis* to manage root-knot nematode infestations successfully and enhance the expression of resistance genes.

Ashokkumar *et al.,* (2021) [3] shown that growth regulators such as salicylic acid, jasmonic acid and indole butric acid (IBA) and biocontrol agents such as *Pochonia chlamydosporia* and *Purpureocilium lilacinum* found to boosts the production of defense-related proteins and defence compounds in guava plants infested with *M. enterolobii.*

Sing *et al.,* (2022) [40] performed treatment with *Purpuecilium lilacinum* in okra seeds at a dosage of 5 ml/kg. This study established the efficacy of *P. lilacinum* as distinct biocontrol agent to suppress *M. incognia* directly by egg parasitism and indirectly by induction of defence compounds within the plants.

Silva *et al.,* (2021) [39] also confirmed that *B. subtilis, B. licheniformis* and *Trichoderma longibrachiatum* are potential resistance inducing biocontrol agents in tomato against *M. enterolobii*. In a study conducted by Jindapunnapat *et al.,* (2013) [23] found that *Trichoderma harzianum* induces defence mechanism in guava against *M. enterolobii* by production of detrimentant chemical compounds.

Jindapunnapat *et al.,* (2013) [23] observed a significant enhancement in enzyme activities in tomato plants due to the application of various bioagents such as *Serratiam arcescens* , *Bacillus subtilis* and *Spirulina platensis*. These enzyme activities exhibited toxicity towards root-knot nematodes, acting as triggers to stimulate the defense response of tomato plants against *M. enterolobii*. The research also revealed that *Serratiam arcescens* demonstrated the highest efficacy in promoting plant defense activation against nematodes, followed by *Bacillus subtilis* and *Spirulina platensis*.

6. Conclusion and future prospective

It is concluded that *M. enterolobii* resistant guava species/varieties/accessions such as *Psidium cattleianum var xysopersicum, P. cattleianum var lucidum, Psidium friedrichsthalianum, Psidium guineense, Acca sellowiana, Psidium rufum,* AUFLA1, AUFLA4, AUFLA5, APASTOG-ROXAG- AMAP and *Psidium guajava* accession S3 has been documented as resistant sources for *M. enterolobii*. Increase in phenols, sugar, protein content and enzyme activities have been observed in resistant plants upon nematode infestation. *Psidium cattleianum* shown resistance by deteriorating giant cell formation. The root exudates of resistant varieties contain compounds that act as a repellent against root knot nematode. Resistant accessions, namely K-10, A-06, and J-16 of *Psidium guajava* have demonstrated compatibility with commercial guava varieties. In contrast, species like *P. cattleyanum* and *P. friedrichsthalianum* have exhibited a compatibility of only

50% success rate with *P. guajava* spp. The application of bioinoculants such as *Bacillus subtilis*, *Pochonia chlamydosporia* and *Trichoderma harzianum* has shown promising result in inducing resistance against *M. enterolobii*. The future strategies like enhancement of nematode screening protocols involving a wider range of *Psidium* spp and improved grafting methods between *Psidium* Species are required. Also, intraspecific hybridization have to be done using different species of *Psidium* plants, aiming to create rootstocks that exhibit resistance to *M. enterolobii*. Further understanding of plant defense mechanisms in resistant plants will allow the selection of desired features for the guava breeding program. New bioinformatics tools and genome sequence data have both become available for efficient dsRNA construction and stacking dsRNA sequences to target several genes for management of nematodes. The identification and functional studies of nematode effector targets utilizing RNAi technology have substantial potential to enhance resistance in guava plants to *M. entereolobii*

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